Hipparcos parallaxes for η Boo and κ^2 Boo: two successes for asteroseismology

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1. Introduction

The release of the Hipparcos catalogue (Perryman et al. 1997) provides an opportunity to check results from asteroseismology. This has already been done for the double-mode δ Scuti star SX Phe: Høg & Petersen (1997) found excellent agreement with the parallax derived from model calculations by Petersen & Christensen-Dalsgaard (1996). Here we show that Hipparcos parallaxes for two other stars are also in good agreement with oscillation results.

2. Solar-like oscillations in η Boo

η Boo is a bright G0 subgiant and a good target for detecting solar-like oscillations. We observed this star over six nights with the 2.5-m Nordic Optical Telescope and, by monitoring equivalent widths of Balmer lines, we detected oscillations with amplitudes at the expected level (Kjeldsen et al. 1995). We measured frequencies for thirteen individual modes in the range 750–950 μHz and determined the large frequency separation to be

$$\Delta\nu = 40.3 \pm 0.3\,\mu\text{Hz}.$$

The measured frequencies were subsequently shown to be consistent with models by Christensen-Dalsgaard, Bedding & Kjeldsen (1995, hereafter CBK95) and also by Guenther & Demarque (1996). In the light of a more accurate luminosity, we can revisit these results. Note that an attempt by Brown et al. (1997) to confirm oscillations in η Boo using Doppler measurements was not successful. Nevertheless, for the present we continue to assume the reality of the detection.

The parameters of η Boo are summarised in Table 1. Our adopted luminosity in CBK95 was based on the best available parallax. The more precise

Table 1. Parameters of η Boo

	Old[a]	New
Parallax (mas)	85.8 ± 2.3^b	88.17 ± 0.75^c
Effective temperature (K)	6050 ± 60^d	
Luminosity ($L_\odot$)	9.46 ± 0.65^e	9.02 ± 0.22^f
Radius ($R_\odot$)	2.81 ± 0.08	2.74 ± 0.036

[a] as adopted by CBK95

[b] Harrington et al. (1993)

[c] Hipparcos Main Catalogue (`http://vizier.u-strasbg.fr/cgi-bin/VizieR`)

[d] Bell & Gustafsson (1989) and Blackwell & Lynas-Gray (1994)

[e] using the above $T_{\rm eff}$, plus the angular diameter of 2.24 ± 0.02 mas given by Blackwell & Lynas-Gray (1994).

[f] using $V = 2.68 \pm 0.01$, $BC - BC_\odot = 0.03 \pm 0.01$ and $M_{V\odot} = 4.825 \pm 0.01$.

Hipparcos parallax, while being consistent with the ground-based value, implies a slightly lower luminosity. Also note that in CBK95 we calculated the luminosity using published estimates of the effective temperature and angular diameter, which were based on the infrared flux method. The calculation, also used by Guenther & Demarque (1996), was indirect and here we prefer to use V-band photometry directly, as explained in the Table. The new luminosity is accurate to 2.4%, an improvement by a factor of three over the value adopted in CBK95.

This improved luminosity constrains the expected oscillation frequencies for η Boo. In Figures 1 and 2 we show the location of η Boo in the H-R diagram (these are similar to Figs. 1 and 2 of CBK95). The evolution tracks use the known metallicity of η Boo ($Z = 0.03$) and the solar value for the ratio of the mixing length to the pressure scale height. Full details of the calculations are given in CBK95.

The diagonal lines in Figure 2 join models of constant $\Delta\nu$. The solid point indicates the 1.6-$M_\odot$ model chosen by CBK95 to have the frequency separation observed by Kjeldsen et al. (1995). *It is clear that the improved luminosity for η Boo is in excellent agreement with the observed frequency separation.*

Guenther & Demarque (1996) also computed models for η Boo. By matching the observed oscillation frequencies, they derived a mass of $1.55 \pm 0.03\,M_\odot$ and predicted a parallax of 89.5 ± 0.5 mas. Their parallax agrees with the Hipparcos measurement, again giving strong support to the reality and interpretation of the oscillation signal.

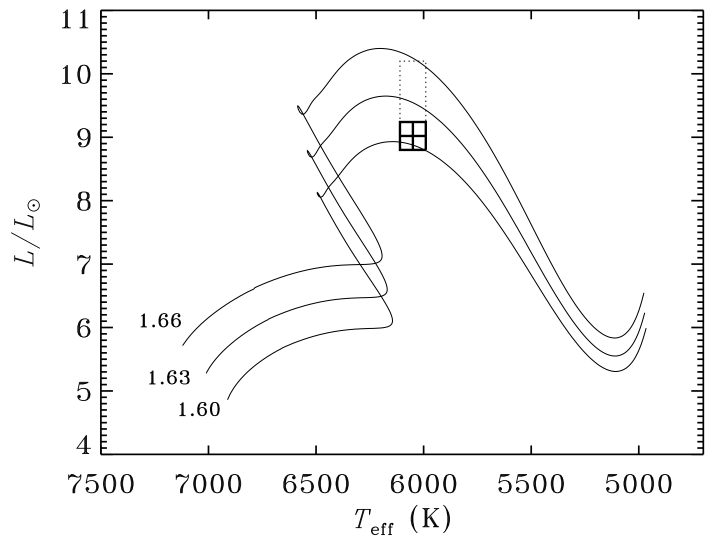

Figure 1. Evolutionary tracks in the H-R diagram for three masses (labelled in $M_\odot$). The error boxes show $(T_{\rm eff}, L)$ for η Boo adopted by CBK95 (dotted lines) and the new values (bold lines).

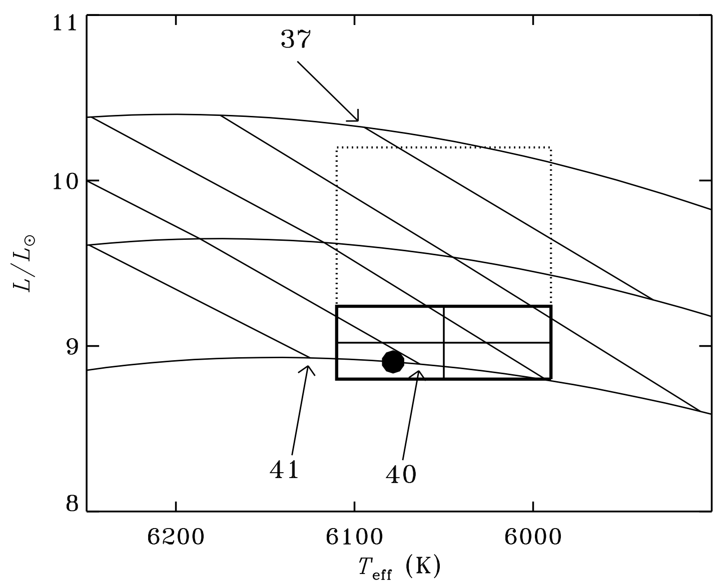

Figure 2. Close-up of the H-R diagram in the vicinity of η Boo. Same as Fig. 1, with the addition of diagonal lines which join models of constant $\Delta\nu$ (37, 38, …, 41μHz), labelled in a few cases by $\Delta\nu$ (in μHz). The solid point indicates the model chosen by CBK95.

3. The δ Scuti star κ^2 Boo

The Aarhus group has also studied the binary system consisting of κ^1 Boo (HR 5328; $V = 6.69$; F1 V) and κ^2 Boo (HR 5329; $V = 4.54$; A8 IV). The brighter component κ^2 Boo is a δ Scuti variable. Based on a model fit to four observed frequencies, Frandsen et al. (1995) derived a distance of 47.9 pc.

The Hipparcos parallax for this system is 21.03 ± 0.83 mas, which implies a distance of 47.6 ± 1.9 pc. This is in excellent agreement with the distance derived by Frandsen et al.. However, we note that their frequency identifications did not allow for rotational splitting, despite the fact that κ^2 Boo is known to be a rapid rotator. Unless the accuracy of the predicted parallax is coincidental, we appear to have confirmed their assumption that the observed modes have $m = 0$.

4. Conclusion

The results presented here for η Boo and κ^2 Boo, together with those for SX Phe by Høg & Petersen (1997), all rely on the same stellar evolution calculations (Christensen-Dalsgaard 1982). The fact that asteroseismic analysis has been successfully performed for three stars covering a range of masses and evolutionary states is an important validation of the models.

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